Section 2: Principles of Erosion and Sediment Control

2.1. Introduction

Erosion is the process by which soil particles are detached by rainfall, wind, ice, gravity or any other action on the soil surface. Once the soil particles are detached, they become sediment suspended in water or wind and are then available for transport. When the water or wind velocity has slowed sufficiently, and for a long enough period of time, soil particles fall from suspension the process of settling out of suspension is called sedimentation. Heavier soil particles, such as sand and gravel, settle more quickly than finer silt and clay particles. For example, coarse sand with a particle size of 0.3 mm may settle one meter in 30 seconds. However, clay with a particle size of 0.0015 may take almost 80 hours to settle one meter. Turbidity is the presence of suspended solids in water, i.e., muddy looking water. This creates a negative environment for water dwelling animals and plant life. Since water erosion is the concern of current regulations, it will be the primary erosive force discussed.

2.2. Types and Causes of Erosion

There are several ways in which the surface of the soil erodes. With water caused erosion, the process begins with the initial soil particle detachment caused by energy impact of raindrops. This is referred to as splash *or* raindrop erosion. Because water is cohesive, or affixes to itself, it will accumulate as a collective force. This collective force flows downstream, eroding the soil in many different ways. As sheet flow, the water accumulates as a thin, broad layer of water. This causes sheet erosion which is generally less destructive than concentrated flows because it usually has less energy or velocity. Sheet flow and sheet erosion usually occur on surfaces that have a relatively flat slope. On steeper slopes, this generally occurs at the top of the slope prior to the water collecting into concentrated flow.

As the water gains velocity and collects in greater quantities, it forms rills or small eroded channels in the soil surface. These rills collect water and as more water collects, the rill grows to form a gully. The difference between a rill and a gully is size and duration. If the soil surface is reshaped, as in tilling, blading or re-grading, the rills do not form in the exactly the same location. However, rills may reform in the area due to water flowing across the surface. With a gully, unless the water above the gully location is redirected, it is likely that the gully will reform in the same location. If gullies are left in place, they can continue eroding the soil until the slope bank fails and creates in-stream damages and stream bed erosion.

Streambank *or* channel erosion is as natural as all other erosion. It is caused by sediment deposition that accumulates on one side and pushes the water to the opposing side thereby eroding the bank. This process is what makes streams and rivers meander. The water system handles natural sediment deposition by covering the soil with vegetation and thereby stabilizing the new soil area. However, channels may become unstable due to increased flows or changes in upstream sediment load.

2.2.1. Runoff Factors

Runoff quantities are going to impact the amount of erosion one can anticipate. The basic factors that are going to influence runoff quantities are:

- Precipitation
- Soil permeability
- Antecedent moisture
- Watershed area
- Land cover
- Adjacent land use

2.2.1.1. Precipitation

Precipitation or annual rainfall for an area will effect erosion. In areas that have relatively low annual precipitation, there may be times during the year that construction activities see no significant rainfall. However, in many arid areas, annual rainfall may be comprised of a few, short duration, but very intense storms.

2.2.1.2. Soil Permeability

Soil permeability or soil characteristics help determine how much runoff will percolate into the soil. Looser soils such as sand will allow the runoff to percolate into the soil. Tighter soils, such as clays, do not allow for much infiltration into the soil. Storm water that does not enter the soil, remains as runoff, and therefore an erosive force. Soil infiltration rates are decreased and runoff volumes are increased when the soil is frozen, regardless of the soil group. Soils, as classified by the Natural Resource Conservation Service (NRCS) fall into four basic Hydrologic Soil Groups based on the soil's runoff potential and are as follows:

> **Group A** has ***low runoff potential and high infiltration*** rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands, gravels, loamy sand or sandy loam types of soils and have a high rate of water transmission.
>
> **Group B** has a moderate infiltration rate when thoroughly wetted and consists chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures such as a silt loam or loam.
>
> **Group C** has a low infiltration rate when thoroughly wetted and consists chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure such as a sandy clay loam.
>
> **Group D** has the ***highest runoff potential*** because they have ***very low infiltration rates*** when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils are usually clay loam, silty clay loam, sandy clay, silty clay or clay.

2.2.1.3. Antecedent Moisture

The antecedent moisture or existing moisture in the soil will influence the amount of runoff infiltration. If a soil has a high water content or high water table, there is little room for additional water. If a soil has a loose structure and is relatively dry, there is greater water infiltration and storage capacity within the soil structure.

2.2.1.4. Watershed Characteristics

The size of the surrounding watershed and location within a watershed area will influence the amount of runoff, and therefore the amount of erosion potential. A site with a surrounding large watershed that drains to the site can anticipate greater quantities of runoff than a site that is at the top of a watershed area or with a small surrounding watershed area.

2.2.1.5. Land Cover

Land cover is an essential component of generated runoff. Vegetation will reduce the runoff velocity, promote infiltration, and capture sediment. However, lack of vegetation or impermeable surfaces will tend to increase runoff velocities and the potential for erosion (See Figure 2-1).

2.2.1.6. Land Use

An erosion potential analysis will include an evaluation of *adjacent* land use. If the surrounding project site has established vegetation, then one can anticipate that much of adjacent storm water will be assimilated by the adjacent land cover. If the project site is next to vast areas of impervious surface, such as a large paved parking lot, then one can anticipate that there will not only be high velocity flows, but the runoff may include litter, debris, and parking lot surface pollutants. Another consideration of paved surface runoff is thermal pollution. As the pavement heats in the summer season, the water flowing into adjacent property and receiving waters is usually a higher temperature than other runoff.

2.2.2. Accelerated Erosion

Natural erosion is generally considered to be due to the influence of climatic forces on the surface of the earth. However, accelerated erosion is natural erosion multiplied by human activity such as construction. Sediment enters receiving waters more rapidly and at far greater concentrations through accelerated erosion. When nature is unable to assimilate the quantities of pollutants, impairment occurs.

Common construction related activities that can accelerate erosion include:

- unrestricted or non-phased development
- removal of surface cover or vegetation
- increased surface imperviousness (i.e., paving).

Phasing construction activities can decrease erosion by leaving existing vegetation in place until construction activity necessitates removal. This requires coordination of land clearing schedules with the installation of erosion control measures. The objective is to minimize the amount of disturbed area at any one time.

Leaving existing vegetation in place helps reduce runoff and erosion because it:

- protects the soil from raindrop impact,
- reduces the velocity of runoff,
- anchors soil in place through the plant root system,
- intercepts soil particles during runoff, and
- increases the infiltration rate of the soil.

However, an increase in impervious surfaces can increase the amount of runoff. According to the Environmental Protection Agency, as little as 10 percent impervious cover in a watershed can result in stream degradation. Figure 2-1 shows the relationship between impervious cover and surface runoff. If sensitive receiving waters are adjacent to paved areas, there is the possibility of thermal pollution from runoff that has been heated by impervious surfaces. The increase in impervious surfaces also increases the peak discharge rates due to minimal infiltration.

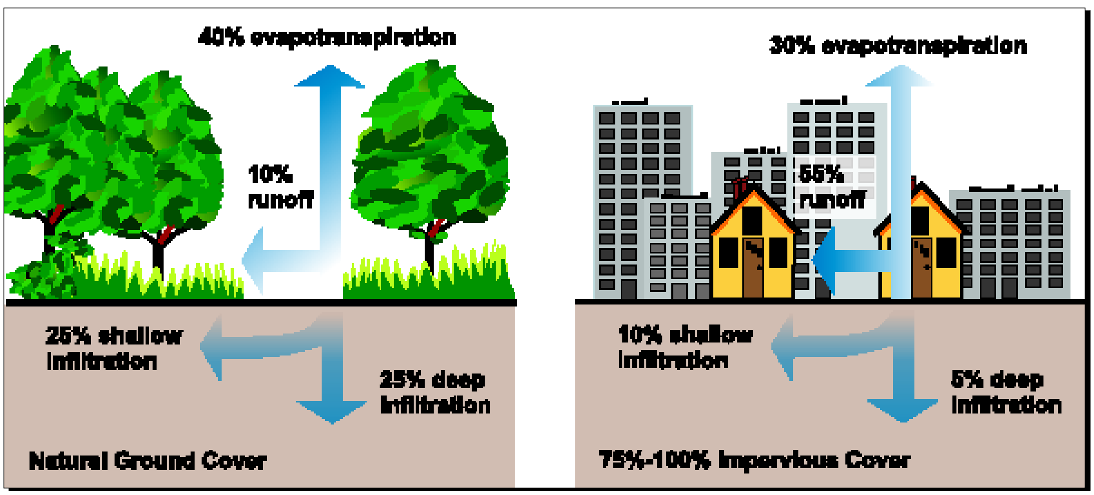

Figure 2-1: Relationship between Impervious Surfaces and Runoff

Source: U.S. EPA

2.3. Erosion Control versus Sediment Control

The terms erosion and sediment control are often misused as if the terms were interchangeable. In fact, they are quite different in both concept and management requirements. Sediment is a product of erosion. Erosion control is any practice that protects the soil surface and minimizes the amount soil particles detached and transported by rainfall or wind. Erosion control is implemented as a source control. Soil is a natural resource that has a significant value, especially in the structural integrity of a highway system. Sediment control is any practice that traps the soil particles after they have been detached and transported. Sediment control begins with erosion control by minimizing the potential sources of sediment. The emphasis should be placed on providing a protective cover on the soil surface, diverting runoff so that it does not flow across disturbed areas, and preserving existing vegetation to maximize soil infiltration and capture sediment.

Erosion controls work in conjunction with sediment controls. Areas under active construction often cannot have immediate erosion control in place. Sediment control measures, such as silt fence, are then used to capture and contain the sediment. A commonly misdirected approach to erosion control is the use of sediment controls, such as silt fence and wattles, without any erosion controls in place. Sediment controls are secondary to erosion controls. Sediment control measures often require more maintenance than erosion control. The sediment build-up needs to be removed routinely to assure proper performance of the control measure. If adequate erosion controls are in place, less sediment will be transported; and therefore less sediment will need to be captured. Protecting the soil surface and keeping the soil in place should be the primary goal in storm water management.

2.3.1. Impacts of Sediment on Water Resources

The EPA has determined that sediment is the number one pollutant being discharged from construction activities. Sediment entering receiving waters is more than just a little soil in the water. Storm water runoff carries contaminants that lie on the soil and pavement surfaces such as pesticides, herbicides, bacteria and other toxic substances. Many of these substances are transported with soil particles and can negatively impact water resources. These impacts may include:

- destruction of spawning areas, food sources, and habitat;
- direct toxicity to wildlife;
- lake degradation;
- sediment deposition of adjacent land;
- siltation of navigation channels;
- impacts to commercial fisheries; and
- reduction of storm water conveyance systems and water storage capacities.

Turbidity from suspended sediment contributes to a decline in water quality. It can reduce available sunlight which reduces photosynthesis and plant growth in aquatic species. This can lead to the destruction of habitat through pollutant laden sedimentation.

Sediment pollution has an impact on natural systems within the water bodies, adjacent land uses such as agriculture, and the surrounding ecosystems. It also has an economic impact. Siltation or sediment deposition within waterways directly affects the navigation ability of vessels using that waterway. Fish habitat, and therefore, sport fishing and the tourism industry is affected by the degradation of water resources. Reduction in water storage capacity in natural systems and infrastructure can increase flooding. There are also costs associated with removal of sediment from storm water conveyance systems and water treatment. Many of these impacts and associated costs are directly related to erosion and the sedimentation that occurs.

2.4. Principles of Erosion and Sediment Control

Ineffective erosion and sediment control measures is not usually the result of a lack of effort. Instead, ineffective controls can usually be attributed to placing BMPs in the wrong application, sediment control placed instead of erosion control, and/or erosion control used where a runoff management tool was needed or simply improper installation. This misapplication usually results in failure of the BMP. The most common problem is using sediment control devices, such as silt fence, as a cure for erosion problems where no erosion control device was implemented. This creates a high maintenance situation for the silt fence as there is no BMP in place to reduce the quantity of soil that is being detached and transported.

The first step in choosing a proper BMP is to decide its function within the strategy for controlling erosion and sediment. Understanding the function an erosion or sediment control BMP is to perform is the first step in achieving cost effective control. In general erosion controls function in the following thee ways:

- Surface protection
- Run-on management
- Velocity control

Sediment controls function by removing any suspended material in storm water runoff before it can leave the site and be transported to adjacent water bodies or courses. Most often sediment controls are designed to capture a predetermined volume of storm water runoff and then remove a significant portion of the Total Suspended Solids (TSS). Sediment controls function in three ways:

- Extended detention or extended in-channel residence time
- Filtration
- Chemical flocculants

2.4.1. Erosion Control

Erosion controls are the most effective means of ensuring that adjacent properties are protected from sediment damage during construction. The objective of all erosion control BMPs is to retain soil particles and other pollutants in place by preventing them from being suspended in storm water runoff. The materials and technologies employed to accomplish this function by protecting the surface, managing storm water run-on and by controlling the velocity of flow over the surface.

2.4.1.1. Surface Protection

Surface protection works by covering the surface of the bare soil in a way that accomplishes two objectives. First, the material must absorb the energy of rain drops impacting the unprotected soil surface. Second, to be effective the material or method must trap and hold in place any soil particles that are dislodged by rain drop impact. There are a numerous materials available to provide this function and should be selected based on a detailed knowledge of the site conditions; soil texture, slope, slope length and climatic variables.

2.4.1.2. Run-on Management

Run-on management tools are designed to utilize proper grading, diversions, barriers, or interceptor ditches to minimize concentrated flows and divert runoff away from denuded slopes or other critical areas. This can be done by minimizing slope steepness and length through the use of benches, terraces, contour furrows, interceptor swales or diversion ditches. The concept is to divert clean runoff before it becomes sediment-laden and convey it down the slope in pipes or lined channels until it can be released into an appropriate undisturbed conveyance.

2.4.1.3. Velocity Control

Velocity reduction is a key component of BMP strategies. Control measures such as rock check dams, wattles, etc., are placed perpendicular to the direction of flow, whether sheet flow or concentrated flow, to slow the velocity of the water by interrupting the flow and helping maintain sheet flow. Concentrated flows generate more energy and velocity than sheet flows. Greater depths of flow and increased velocity results in more erosion and suspension of eroded materials. If concentrated flows develop, control measures, such as check dams, can be used to reduce the velocity. Where concentrated flows are directed to uniform surfaces, level spreaders can be used to reestablish sheet flows. Level spreaders can also improve the efficiency of other facilities, such as vegetated swales, filter strips, or infiltration devices which are dependent on sheet flow to operate efficiently the BMP type must be selected based on the anticipated depth of flow, velocity, and frequency of flows over the surface or in the channel.

2.4.2. Sediment Control

Effective sediment control measures are designed and implemented to capture suspended materials by extending the residence time in channels or physically capturing a predetermined volume of water in order to remove the suspended sediment material. The removal of suspended solids can be affected in three ways; extending the detention time of storm water run of in a channel or basin, filtering the sediment from the water through some type of filtration medium, or by using chemical flocculants.

2.4.2.1. Extended Detention

Detention is the most common means of providing sediment control on construction sites. Extended detention can be affected by interrupting flows or by actually capturing a water volume in a basin or sediment trap. Current regulations require that a volume of one acre-inch (3,600cf or 102cm) be provide for each acre of watershed contributing to an outlet. Table 1 provides some accepted rates of settling for solids based on particle size.

Table 1 Settling Rates of Sediment Materials by Particle Size

Diameter of Particle (mm)	Order of Size	Settling Velocity (mm/sec)	Time Required to Settle One Meter (3.28 ft)
10.0	Gravel	1000	1.0 seconds
1.0		100	9.8 seconds
0.6	Coarse Sand	63	15 seconds
0.3		32	30 seconds
0.15	Fine Sand	15	67 seconds
0.015		0.35	47.6 minutes
0.010	Silt	0.154	107 minutes
0.003		0.0138	20.1 hours
0.0015	Clay	0.0035	79 hours
0.0010		0.00154	180 days
0.0001		0.0000154	754 days
0.00001	Colloidal Particles	0.000000154	207 years
NOTE: temperature 50° C; all particles assumed to have specific gravity of 2.65			

2.4.2.2. Filtration

Filtration is also used to as a means of sediment control on construction sites. Silt fence is usually considered a filtration BMP because it is suppose to slow the flow of water and filter the suspended materials from the storm water stream. However, silt fence fabrics are easily filled by solids and usually end up functioning as detention structure rather than a filter. Research is demonstrating that the most effective filtration devices are rock check dams, filter socks or rolled materials such as coir wattles and sediment bags. Simple rock check dams or rock checks that include cores of some type of filter material such as sand, activated charcoal or compost. Filter socks are synthetic fiber tubes filled with a filter medium of compost, mixed compost and wood chips or some other friable filtration medium. Rolled products or wattles also provide some filtration when used in channels and on slopes. Sediment bags are large bags fabricated from synthetic fabrics similar to silt fence. Storm water is usually pumped into the fabric bag which allows the storm water to drain slowly trapping the sediment in the bag. These have achieved some popularity in sensitive areas where work space is limited.

2.4.2.3. Chemical Flocculants

Chemical flocculants are being employed to remove suspended materials form storm water. The greatest benefit seems to be in removing very fine particulate matter from suspension when draw down times are limited. These are specialized materials and do not have broad application for sediment control on transportation construction sites.